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SURFACE-LIGHT SOURCE ELEMENTS

CLAIM(S)

A surface-light source element comprised a first element having an incident surface at least on its one side surface, a light emission surface orthogonal to said incident surface, and a reflection layer on the surface opposing to the light-emission surface and a second element having an incident surface for taking in the emission light from said first element and a light-emission surface for emitting the light in prescribed direction, said surface-light source element being characterized in that, on the light emission surface of said first element, multiple lens units are formed to emit the light in the prescribed direction orthogonal to the light advancing direction, and in that multiple prism units are formed on the incident surface of said second element.

DETAILED DESCRIPTION OF THE INVENTION

(Field of Industrial Application)

The present invention pertains to a surface-light source element for use in surface light source device. The element of the present invention is appropriate for use as a back illumination means for a liquid crystal display device.

(Prior Art)

With the prior art back illumination means of a liquid crystal device in general, a linear lamp used as a light source is placed on the focus of a rotating radial reflector, and a bowl shaped diffusion plate is placed on top of the lamp in most cases. However, an attempt is now being made to optimize the shape of the reflector and adjust the diffusivity of the diffusion plate.

Also, there are special types as follows: a type wherein a linear lamp and a conductor are combined, and the shape of the conductor is processed into nearly a curved shape to make the emission light to be converged in a specific direction by approximating a point-source light; a type wherein the thickness of the conductor is changed along the advancing direction of the light; a type that uses a lenticule in which a prism angle is changed depending upon the distance from the light source; and a type wherein some of the above are combined. By the point-source light approximation, the light path can be simulated in most cases, and according to this, the shape of the photo-conducting layer that accords with it can be changed according to the distance in the light advancing direction. This idea has already been disclosed in many Japanese Patent applications and utility model applications.

However, most of the surface-light sources aim to emit the light uniformly in the whole direction but, some cases, the light needs to be converged in a specific direction depending upon use purposes.

With the liquid crystal color TV for personal use having a small angle of field,

it is expected that the light should be emitted only in one specific direction and the a uniform light amount should be emitted from the whole emission surface. Fig. 3 shows a schematic diagram of the liquid crystal color TV device of this type. In the figure, 1 indicates the liquid crystal image screen, 2 the liquid crystal color TV device body, 3 a normal line in the liquid crystal image screen, and 4 eyes of an viewer. In the device of this type, the liquid crystal screen 1 is positioned at 45° to the body 2 of the liquid crystal color TV device, and the screen is viewed from the position at 15° to the normal line 3. Therefore, if the back illumination means can make the surface light source brightness level higher in the angle regions shown by X in the figure than in the other angle region, it will be advantageous in terms of converging the entire light amount there. The brightness level of such a surface-light source is highest in the desired direction, and this brightness level is many times higher than that in the type that emits the light uniformly in the whole direction. So, if this type of back illumination means is used for a display device having an angle of field in one specific direction, a display device that can produce a high brightness level while using low power consumption can be manufactured.

(Problems of the Prior Art to Be Addressed)

For the light source used for a planar surface of a liquid crystal color TV device shown in Fig. 3, however, a point-source light is hardly used in most cases except the case when a special small dimension is used for the TV device, but the light source used is a volume-light source (a light source that cannot be defined as a

point-source light), and the point-source light approximation is not consistent at all. Therefore, the shape proposed by the prior art cannot produce desirable characteristics in spite of its precise and complex shape and of high manufacturing cost.

In addition, the volume-light source such as that for a fluorescent lamp has a diffusion light source with non-directivity. Accordingly, it is extremely difficult to secure the desired directivity by using a diffusion emission-light source.

In order to accomplish the aforementioned objective, in addition to the desired emission light directivity, the size of the light source device needs to be reduced to the smallest possible size, so its thickness should be nearly as thick as the diameter of the light source lamp. With the aforementioned light source device, wherein a rotating radial type reflector is positioned at the bottom of the lamp, its thickness is 2 - 4 times more than the lamp diameter, and the requirement of a small size cannot be met.

(Means to Solve the Problems)

To solve the aforementioned problems, the present invention aims to present a surface-light source, which is thin (as thin as the diameter of the lamp) and easily produces the convergent light in the direction toward viewers eyes without increasing the power consumption for the back illumination of the display device having a small angle of field and a limited visible field, such as a liquid crystal color TV device.

The aforementioned objective can be accomplished by a surface-light source element comprising a first element having an incident surface at least on its one side surface, a light-emission surface orthogonal to said incident surface, and a reflection layer on the surface opposing to the emission surface and a second element having an incident surface for taking in the emission light from said first element and an emission surface for emitting the light in the prescribed direction.

On the light emission surface of said first element, multiple lenses are formed to emit the light in the prescribed direction orthogonal to the light advancing direction, and on the incident surface of said second element, multiple prisms are installed.

The surface-light source element of the present invention is further explained below with reference to the drawings.

A basic theory of the surface-light source element of the present invention is explained below.

The photo-conductor's light refractive index n to the air is generally in the neighborhood of 1.5 - 1.6. In the structure (edge lighting type), wherein the incident side surface 12 and the incident side surface 11 of the photo-conductor cross with each other, the critical reflection angle is nearly 45°, and the light is theoretically not emitted from the emission surface 12. In Fig. 4a, 14 indicates the light source for a fluorescent lamp, 15 its reflector, and 13 the reflection surface formed on the opposite side to the emission surface 12 of photo-conductor 10.

Therefore, generally, the emission surface 12 is processed into diffusion emission surface 12a or the reflection surface 13 opposing to the emission surface is processed into the diffusion reflection surface 13a. But, the emission light, for its being the diffusion light, does not meet the objective of the present invention that wants a directivity of the emission light, so such a means is not usable.

Therefore, there can be considered a structure, wherein a group of linear convex lenses 16 sharing the same linear shape orthogonal to the light advancing direction are formed on the emission surface; on the surface opposing to the emission surface, is formed the reflection surface 13, on one end of which linear light source 14 like a fluorescent lamp is installed in parallel to said group of linear convex lenses. Fig. 5a indicates a perspective view of such a structure, and Fig. 5b shows a profile of its A-A section.

In this geometrical positional relationship, the light emission direction has 40-60° to the normal line in the orthogonal direction to the linear lenses, so there is no emission in the normal direction (Fig. 5b).

Fig. 6a, b show the angle distribution of the emission light brightness level in the structure of Fig. 5b. In other words, this figure shows the rate of emission light in each angle when the emission light in the largest angle is defined as 100%. Fig. 7a, b show the method for measuring the emission light in each angle.

Fig. 7a shows an anterior view of the surface-light source element showing the measuring position. Fig. 7b shows a profile of the section A-A in Fig. 7a. In Fig.

7b, 40 indicates a brightness level indicator.

Fig. 6a shows the angle distribution of the emission light brightness level at the central point (1) shown in Fig. 7, and Fig. 6b shows the angular distribution of the emission light brightness level at the position (2) 10 mm away from the lamp. It is evident from these graphs that there is no emission light in the direction of a normal line.

Therefore, this invention reversely uses a group of lenses 16, wherein the emission light converges in a specific direction and the emission light is small in distribution but large in amount, and the emission lights, 20, 21, emitted from both sides of the normal line (Fig. 5b) are refracted by a group of prisms constituting the second element; thereby converging the emission light in the prescribed direction.

Fig. 8a, b show expanded views of the prism which is another constituent element contributing to the aforementioned operation. In the figure, 20 and 21 indicate the emission lights emitted from the group of lenses 16 of the second element into the right and left directions, respectively; θ_1 and θ_2 are the angles formed by the normal line and the prism surfaces 30 and 31, respectively; 32 indicates the emission surface. In the same figure, ψ_1 - ψ_6 and ψ_1 - ψ_6 show the angles formed by the prism surfaces and the normal line, respectively. The angles are shown by Fig. 8a, b.

When the light comes in from the right side of the prism as the emission light 21 does, it comes in from the prism surface 30, is totally reflected at prism surface

31, and is emitted from the emission surface 32 at the prescribed angle ϕ_6. These prescribed angles ψ_6 and ϕ_6 can be adjusted by the emission angle and by the shape of the group of lenses constituting the first element, the angles θ_1, θ_2, and by the refraction index n of each lens unit.

In addition, the shape of the lens 16 of the first element is not limited to a specific shape as long as it can converge the emission light in the prescribed direction, minimize the emission light distribution, and maximize the amount of the emission light. Depending upon the shape of the group of lens 16 of the first element, the emission angle of the primary emission light does not necessarily become symmetrical to the normal line. In such a case, however, the desired emission angle can be obtained by adjusting prism angle (θ_1 and θ_2 in Fig. 8) of one prism, which is a constituent unit of the prism group of the second element.

In one special example, converging the emission light from the first element into the normal line direction by the second element requires that the emission light of the first element is emitted at 60° to the normal line. This can be done by setting the prism angle (Fig. 8, θ_1, θ_2) at $\theta_1 = \theta_2 = 30°$.

(Embodiment)

The structure of the surface-light source of the present invention is explained in detail below with reference to the drawings.

Fi.g 1 shows a partial profile of the surface-light source as one embodiment example, which corresponds to Fig. 5b.

In the figure, 14 indicates the light source of the fluorescent lamp, 15 its reflector, and 13 the reflection surface formed on the opposite side to the emission surface 12 of the photo-conductor 10. In the figure, 16 indicates the lens unit, 40 the prism unit, and 32 the emission surface. The lens unit 16 and prism unit 40 both have a linear convex shape extending in parallel to the light source (lamp).

The structure of this embodiment example consists of first element 50 having at least one end side 11 of the photo-conductor as the incident surface, the surface orthogonal to this incident surface and mounted with said lens units 16 as the light emission surface, and the opposing surface to the emission surface as the reflection layer 13, and of second element 51 having the incident surface taking in the emission light from the first element 50, prims 40 emitting the light in the prescribed direction, and the emission surface 32 emitting the light taken in from the prim 40. The light emitted from each lens 16 is emitted like the light rays 54 and 55, and the lens unit and prism unit are preset so as to form almost the same angles ψ_6 and θ_6 to accomplish the objective of the present invention.

Fig. 2 shows an example wherein the emission light from the first element is emitted at 60° symmetrically to the normal line, and the angle (θ_1 and θ_2 in Fig. 8) of the prism unit of element 51 is set at $\theta_1 = \theta_2 = 30°$. In the example, the emission light from the emission surface 32 of the second element can be converged in the direction of the normal line like the light rays 56 and 57.

As for the material constituting the elements, an acrylic resin, which has a

highest visible light transmission index as a photo-conductor, is appropriate to meet the purpose of a small size and lightweight. But, it is not limited only to this material.

As the light source 14, a small sized fluorescent lamp is used, but a continuous type linear light source (e.g., filament lamp) may also be used.

In the following example, the prism angle is determined by the first element to make the primary emission angle symmetrical to the normal line. When the emission angle is non-symmetrical to the normal line, it can be simply computed by changing the incident light angle to the right or left. In addition, n indicates the refraction index of the material constituting the elements.

(1) In case when the light comes in from the left side of the prism, the computation (The symbols are those shown in Fig. 8a) is as follows:

(i) $90^\circ - \psi < \theta_1$. $\phi_1 = (\theta_1 + \psi) - 90$.

$\sin \phi_2 = \sin (\theta_1 + \psi - 90) / n$.

$\phi_3 = 90 - (2\theta_2 + \theta_1 - \phi_2)$.

$\sin \phi_4 = n \times \sin \phi_3$.

$\phi_4 = \sin^{-1} (n \times \sin \phi_3)$

(ii) $90^\circ - \psi > \theta_1$, $\phi_1 = 90 - (\theta_1 + \psi)$.

$\sin \phi_2 = \sin (90 - \theta_1 - \psi) / n$.

$\phi_3 = 90 - (2\theta_2 + \theta_1 + \phi_2)$.

$\sin \phi_4 = n \times \sin \phi_3$

(iii) $90^\circ - \psi = \theta_1$, $\phi_1 = 0$,

$\phi_3 = 90 - (2\theta_2 + \theta_1)$.

(2) In case when the light comes in from the right side of the prism, the computation (The symbols are those shown in Fig. 8b) is as follows:

(iv) $90^\circ - \psi < \theta_2$.

$\psi_1 = (\theta_2 + \psi) - 90$.

$\sin \psi_2 = \sin (\theta_2 + \psi - 90) / n$.

$\psi_3 = (2\theta_1 + \theta_2 - \psi_2) - 90$.

$\sin \psi_4 = n \times \sin \psi_3$

(v) $90^\circ - \psi > \theta_2$.

$\psi_1 = 90 - (\theta_2 + \psi)$.

$\sin \psi_2 = \sin (90 - \theta_2 - \psi) / n$.

$\psi_3 = (2\theta_1 + \theta_2 + \psi_2) - 90$.

$\sin \psi_4 = n \times \sin \psi_3$

(vi) $90^\circ - \psi = \theta_2$, $\psi_1 = 0$.

$\psi_3 = (2\theta_1 + \theta_2) - 90$.

$\sin \psi_4 = n \times \sin \psi_3$

When an acrylic resin is used for the material of the prism, the refraction index is n = 1.49. If the angle of the incident light into the prism that is symmetrical to the normal line is $\psi = 55^\circ$, then, by the above computation, the angle at which the emission light from the prism is converged on one side of the normal line is obtained (an example of the computation wherein the difference between the right and left is 2° or less is).

incident angle $\psi = 55°$		left side prism angle θ_1	right side prism angle θ_2
θ_1(in degree)	θ_2 (in degree)	light from left side (ϕ_6)	light from right side (ψ_6)
32	25	8.9	8.5
33	24	11.5	11.0
34	23	14.0	13.5
35	22	16.5	16.0
36	21	19.1	18.6
37	20	21.7	21.1
38	19	24.3	23.7
39	18	26.9	26.3
40	17	29.6	29.0
41	16	32.3	31.7
41	15	35.1	34.4

Moreover, when a polycarbonate resin is used for the material of the prism, the refraction index is n = 1.59. By using the same parameters, the index can be computed as follows (the difference between the right and left incident angles is 2° or less, and $\psi = 55°$).

θ_1 in degree	θ_2 in degree	light from the left side (θ_6)	light from the right side (ψ_6)
32	25	9.7	8.4
33	24	12.4	11.0
34	23	15.0	13.6
35	22	17.7	16.2
36	21	20.3	18.9
37	20	23.1	21.6
38	19	25.8	24.3

39	18	28.6	27.0
40	17	31.4	29.8
41	16	34.3	32.6

Based on the above computation, the back surface light source of 3-inch liquid crystal color TV is assumed here, and the panel size was preset at 61 mm x 56 mm (horizontal length x vertical length).

In the following embodiment example, a 5 mm thick transparent acrylic resin was used for the first element, and a 1 mm thick acrylic resin and polycarbonate resin were used for the second element. But, the size, thickness, and material are not necessarily limited to them.

(Detailed Embodiment Examples)

(Embodiment Example 1)

To make the first element by using a mold for the multi-line lens with pitch 0.38 mm and smooth curved surface with height 0.38 mm, the pattern of this mold was transferred to a 5 mm thick acrylic resin sheet by a heat press. On the other hand, the angle of the effective field of the portable liquid crystal TB screen and the inclination angle (Fig. 3) to the normal line were measured. Then, the emission angle was preset at 15° ($\psi_6 = \theta_6$), and the left prism angle was preset at 35°(θ_1) and the right prism at 22°(θ_2) (Fig. 8a, b). A mold having a multi-prism pattern with prism's apex angle 57 ° ($=\theta_1 + \theta_2$) and pitch 0.38 mm was made, and the pattern was thermally transferred to the 1 mm thick acrylic resin sheet to make the second

element. Each element was cut into a specific size.

Then, two horizontal laterals with 61 mm were polished by a conventional method, and to the two vertical laterals with 56 mm, was bonded a polyester film coated with an aluminum-deposited film with an adhesive. Then, on the opposing surface to the transferred lens surface, a polyester film coated with a silver-deposed film was installed. Along the two 61 mm horizontal laterals of the first element, a lamp with diameter 8 mm and length 90 mm (FLE - 8.90 ADIP 3 by Elebamu Co.) was installed by winding an aluminum foil on it as a reflector and was lit with DC5 V via an inverter. The center section of the first element was measured at its center and on the side of the lamp (Fig. 7a) by a brightness indicator (Brightness indicator nt-1 made by Minolta Co.) by changing the angle to the normal line to find the emission light distribution (Fig. 7b). The data thus sought are shown in Fig. 6a, b, and their peak values are indicated in Table 1.

Table 1

brightness level values on the left and right sides to the center point
3500 and 3200 cd/m^2
brightness level values on the left and right sides 10 mm away from the lamp
4000 and 3800 cd/m^2

Moreover, on the first element, the second element was mounted applying the prism side of the second element to the lens side of the first element and secured by

applying a nearly 5 mm wide two-side adhesive tape along the lamp edge. The emission light distribution of the second element was sought by measuring by the same method as that used for the first element. The data are shown in Fig. 10a, b, c. The peak brightness level values at these points and the peak emission light angle are shown in Fig. 2.

Table 2

	peak brightness level values	peak emission light angles
center point (1)	3100 cd/m^2	15°
point at 10 mm away from the lamp (2)	3500 cd/m^2	20°
point at 10 mm away from the lamp (3)	3700 cd/m^2	12°

At the emission angle peak 12 - 20°, the light is converged, and the distribution angle was nearly 40°.

The tube surface brightness level value while the lamp was being lit was 10,000 cd/m^2.

(Embodiment Example 2)

The same first element used in embodiment example 1 was used. As for the second element, the same transfer mold as that used in embodiment example 1 was used. But the thickness of the material was changed to a 1 mm thickness for the

polycarbonate resin. By using the same presetting, the emission angle distributions were measured by the brightness level values. The data are shown in Fig. 11 a, b, c. The peak brightness level values of these points and the peak emission angle are shown in Table 3.

Table 3

	peak brightness level values	peak emission light angles
center point (1)	3200 cd/m^2	17°
at point 10 mm away from the lamp (2)	3700 cd/m^2	23°
at point 10 mm away from the lamp (3)	3400 cd/m^2	12°

(Embodiment Example 3)

The same first element as that used in embodiment example 1 was used. Although the emission angle 60° is necessary requirement for the emission angle to be in the same direction as that of the normal direction, Fig. 6 a, b indicate that the brightness level value is higher than 90% of the peak value at emission angle 60°. Therefore, a mold with multi-prism pattern having prism angle $\theta_1 = \theta_2 = 30°$ and pitch 0.38 mm was made. This was thermally transferred by a heat press to a 1 mm thick acrylic resin to make the second element.

By using exactly the same presetting as that used in embodiment example 1, the emission angle distributions were measured by the brightness level values. The

data are shown in Fig. 12 a, b, c. The peak brightness level values and the peak emission angle are shown in Table 4.

Table 4

	peak brightness level values	peak emission angle
center point (1)	2900 cd/m^2	0°
point 10 mm away from the lamp (2)	3100 cd/m^2	-5°
point 10 mm away from the lamp	3200 cd/m^2	7°

(Comparative Example)

Rutile type titanium oxide 1.5 weight% was dry-blended in acrylic pellets (Hibet HBS made by Mitsubishi Rayon Co.), and a 50 μ thick film was formed by a conventional extrusion machine. The film was spread on an inorganic flat glass sheet shutting the air out. The film, after tentatively secured with methyl terephthalate, was polymerized by a conventional method, and thus a 5 mm thick acrylic resin sheet was obtained.

(Comparative Evaluation)

The comparative example sheet thus obtained was cut up into a 61 mm x 56 mm (horizontal length x vertical length) size. The two horizontal laterals were polished by a conventional method. To the two vertical 56 mm laterals, a film coated with a vapor-deposited film with an adhesive was bonded, and a polyester

film coated with a silver-deposited film was installed on the opposing surface to the white thin film formed on the sheet surface (same as in embodiment example 1). Then, the evaluation was done by using the same method as that used for measuring the first element in embodiment example 1. The data are shown in Fig. 13 a, b. The brightness level values of these points are shown in Table 5.

Table 5

	peak brightness level values
center point (1)	900 cd/m^2
at points 10 mm away from the lamp (2), (3)	1200 cd/m^2

(Conclusion)

As is evident from Fig. 10 a, b, c, and Fig. 13 a, b, the comparative example has the characteristics that the light is emitted evenly in every direction, whereas the surface-light source element of the present invention can converge the light in a specific direction and produces an advantage that the peak brightness level value at the center point of the light is nearly 3.5 times higher.

(Detailed Embodiment Example 2)

(1) Making variant forms of the first elements

As explained above, the shape of the lens of the first element is not limited to a specific shape as long as it converges the light into a specific direction, minimizes the emission light distribution, and maximizes the emission light amount. As examples

of such a lens shape, the following first elements were formed including the first element of the convex cylindrical lenticule lens in the aforementioned detailed embodiment example 1.

1. The first element having nearly the same shape of lens as that of convex cylindrical lenticular lens of Fig. 9:

pitch P = 0.38 mm

height = 0.05 mm

thickness of the first element t = 6 mm

2. Triangle-columnar (sic) lenticule lens having the shape shown in Fig. 14.

pitch P - 0.5 mm

peak angle $\theta = 25°$

thickness of the first element t = 6 mm.

3. Concave lenticule lens shown in Fig. 15.

cylindrical cancave pitch P = 0.5 mm

depth D=0.06 mm

thickness of the first element t = 6 mm

4. Pyramid-shaped lenticule lens shown in Fig. 16.

pitch P_1=0.10 mm, $\theta_1 = 30°$

pitch P_2=0.15 mm, $\theta_2 = 10°$

pitch P_3=0.15 mm, $\theta_3 = 5°$

overall pitch P=0.8 mm

height H=0.097 mm

thickness of the first element t = 6 mm

5. Anisotropic lenticule lens shown in Fig. 17

1) Anisotropic lenticular lens A shown in Fig. 17a

pitch P=0.41 mm

height H_1=0.051 mm

thickness of the first element t = 6 mm

2) Anisotropic lenticule lens B shown in Fig. 17b

pitch P=0.41 mm

height H_2=0.102 mm

the thickness of the first element t = 6 mm.

These first elements were made by transferring the pattern by a heat press to a 6 mm thick acrylic resin sheet by using the molds each having the prescribed pattern.

(2) Emission characteristics of each of the first elements

By using the same method as explained in Fig. 7b, the angular distribution of the emission light brightness level of the first element was sought. More specifically, the two 61 mm horizontal laterals of the first element were polished by a conventional method, and to the two 56 mm vertical laterals, the polyester film coated with an aluminum-deposited film with an adhesive was bonded. On the opposing surface to the transferred lens surface, the polyester film deposited with

silver was installed. Along the two 61 mm horizontal laterals of the first element, a lamp with a 8 mm diameter and a 90 mm length (FLE - 8.90 ADIP3 made by Elebamu Co.) was installed and an aluminum foil was wound as a reflector. The lamp was lit via an inverter by DC 5V. This structure is called surface type. When the angular distribution of the emission light brightness level was examined, since the lens 16 of the first element 50 was facing toward the reflection surface 13, the lens surfaces of the aforementioned elements 1 - 5 were made to face toward the mirror after reflecting the light from the lens 16 at the reflection surface 13, and the angular distribution of the emission light brightness level was measured in order to confirm whether or not the structure to emit the light from the emission surface 30 can be used (hereinafter called back surface type). The process of measuring is shown in Fig. 18 using an example using the convex lenticule lens.

<u>The result of measuring the angular distribution of emission light brightness level</u>

1) Fig. 19 (b) shows the angular distribution of the emission light brightness level of the back surface type first element that uses a cylindrical convex lenticule lens. As a comparative example, the brightness distribution is shown in Fig. 19a. The peak brightness level was nearly in the direction of 70° to the normal line in case of the back surface type, and in the direction of 70-80° to the normal line in case of the front surface type.

2) Fig. 20a shows the angular distribution of the emission light brightness level of the front surface type first element that uses a triangle-columnar lenticule

lens. The brightness level distribution of the back surface type is shown in Fig. 20b. The peak brightness level was in the direction of 70 - 80° to the normal line, and 30 - 35° to the normal line in case of the back surface type.

3) Fig. 21a shows the angular distribution of the emission light brightness level of the back surface type first element that uses a cylindrical concave lenticule lens. The brightness level distribution of the back surface type is shown in Fig. 21b. The peak brightness level was 75 - 80° to the normal line in both front surface type and back surface type.

4) Fig. 22a shows the angular distribution of the emission light brightness level of the front surface type first element that uses a prism shaped convex lenticule lens. The brightness level of the back surface type is shown in Fig. 22b. The peak brightness level was 75 - 80° to the normal line in both the front surface type and in back surface type.

5) Fig. 23a shows the angular distribution of the emission light brightness level of the first element that uses an anisotropic lenticule lens A. The brightness level distribution of the anisotropic lenticule lens B is shown in Fig. 23b. The peak brightness level was in the direction of nearly 60° to the normal line in case of A, and in the direction nearly 50° to the normal line in case of B.

(3) Making of each surface-light source element

On the surface of each first element made by the aforementioned method, the aforementioned second element (nearly the same one as that used in detailed

embodiment example 1) is placed matching the both elements, and the surface-light source element, wherein the lens surface 16 of the first element is present on the emission surface 30 (front surface type) was made.

On the other hand, on the lens surface of each of the first elements, a silver-deposited polyester film was installed. The second element was placed on the opposing surface to this lens surface of the first element matching both elements. Thus, the surface light source element, in which the lens surface 16 is present at the opposing side to the emission surface 30 (the back surface type) was made. The front surface type and back surface type surface-light source elements that use a convex lenticule lens are shown in Fig. 24 a, b.

(4) Measuring the brightness level of each surface-light source element

The peak brightness level, its angle, and the distribution angle of each surface-light source element were examined. The result is shown in Table 6. The distribution angle here refers to the range of an angle in which the brightness level reaches a 50% of the peak brightness level.

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Table 6

shape of lenticule of the first element		apex angle of prism of second element	peak		distribution angle in degrees
			brightness level in cd/m^2	angle in degrees	
convex (Fig. 9)	front surface type	63°	3200	16	55
	back surface type	63°	3000	17	77
triangle-columnar shape (Fig. 14)	front surface type	66	2350	15	75
	back surface type	30	2300	16	90
concave (Fig. 15)	front surface type	63	3100	14	60
	back surface type	63	2950	14	60
convex (Fig. 16)	front surface type	63	3140	16	85
	back surface type	63	3080	14	65
anisotropy (Fig. 17)	A	52	3450	16	95
	B	52	3800	16	55

As is evident from Table 6, with the surface-light source elements equipped with the first elements having the convex lenticule, prism, concave lenticule, convex prism, respectively, the back surface type has a lesser brightness level than the surface type by only a slight difference, so the back surface type is still good enough for practical use.

(5) Emission light distribution of each surface-light source element

The emission light distribution from the center (position 1 in Fig. 7a) of each of the surface-light source element was measured according to the method for measuring the emission light distribution of the first element.

1) Fig. 25b shows the angular distribution of the emission light brightness level in the back surface type surface-light source element using the first element having the lens unit that has the same shape as that of a cylindrical convex lenticule lens shown in Fig. 9. As a comparative example, the brightness level distribution of the front surface type is shown in Fig. 25a. In the back surface type, the emission angle peak showed the converged light at 15-20°, and the distribution angle was nearly 57°. In case of the back surface type, the emission angle peak showed the converged light at 15-20°, and the distribution angle was nearly 77°.

2) Fig. 26a shows the angular distribution of the emission light brightness level in the front surface type first element using a prism lenticule lens. Also, the brightness level distribution of this surface type is shown in Fig. 26b. The emission angle peak showed the converged light at 13-15° in the front surface type and its

distribution angle was nearly 75°. Also, in case of back surface type, the emission angle peak showed the converged light at 15 - 17°, and the distribution angle was nearly 90°.

3) Fig. 27a shows the angular distribution of the emission light brightness level in the back surface type first element using a cylindrical concave lenticule lens. Also, the brightness level distribution of the back surface type is shown in Fig. 27b. The emission angle peak showed the converged light at 13 - 15°, and the distribution angle was nearly 60°. Also, in case of the back surface type, the emission angle peak showed the converged light at 13 -15° and the distribution angle was nearly 60°.

4) Fig. 28a shows the angular distribution of emission light brightness level in the front surface type first element using a convex prism lenticule lens. The brightness level distribution of the back surface type is shown in Fig. 28b. The emission angle peak showed the converged light at 15 -17° in the front surface type, and the distribution angle was nearly 85°. In case of the back surface type, the emission angle peak showed the converged light at 13 - 15° and the distribution angle was nearly 65°.

5) Fig. 29a shows the angular distribution of the emission light brightness level of the first element using an anisotropic lenticule lens A. The brightness level distribution of the anisotropic lenticule lens B is shown in Fig. 29b. The emission angle peak showed the converged light at 15 - 17° in case of (a) and the distribution angle was nearly 95°. The emission angle peak in case of (b) showed the converged

light at 13 - 17° and the distribution angle was nearly 55°.

(6) Conclusion

As shown in Fig. 10 - Fig. 23, regardless of the fact that the emission light of the first element is symmetrical or non-symmetrical to the normal line, the converged light can be emitted at the prescribed angle, as shown in Table 6, and in Fig. 25- Fig. 29, as long as the shape of the second element is properly selected, and the brightness level good enough for practical use can be obtained (2 - 3.5 times brighter than the emission in the whole direction).

(Advantage)

As explained above, by the surface-light source of the present invention, the following advantages can be produced.

1) A thin light source device (as thin as the diameter of the lamp) that can produce the converged light without increasing the power of the light source can be offered for the back surface illumination of a display device of a small liquid crystal color TV with a limited field.

2) The converged light can be easily produced by using a fluorescent lamp which is a diffusion light source, and the emission direction of the converged light can be simply and freely determined (The very similar effect can be produced by creating a focus by a convex lens.)

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 and Fig. 2 show the profiles of the surface-light source element of the present invention.

Fig. 3 shows the relative angle of a liquid crystal color TV to the eyes of a viewer.

Fig. 4 shows a profile of the prior art surface-light source device.

Fig. 5 a, b show a perspective view and a profile of the first element of the present invention, respectively.

Fig. 6a, b show the angular distributions of the emission light brightness levels of the first element, respectively.

Fig. 7a shows an anterior view of the device of the present invention (lamp) (1, 2, and 3 indicate the measuring points.), and Fig. 7b indicates a profile of the A-A section of Fig. 7a.

Fig. 8 shows a graph analyzing the light path when the peak light has entered the prism from the first element.

Fig. 9 shows one example of the lens unit of the first element.

Fig. 10a, b, c show the graphs indicating the angular distributions of the emission light brightness levels in the first embodiment example of the present invention, respectively.

Fig. 11a, b, c show the graphs indicating the angular distributions of the emission light brightness levels in the second example embodiment.

Fig. 12a, b, c show the graphs indicating the angular distributions of the emission light brightness levels in the third embodiment example.

Fig. 13a, b, show the graphs indicating the angular distributions of emission light brightness levels in the comparative example.

Fig. 14 shows a drawing indicating the lens unit of the first element being a triangle-columnar lenticule lens.

Fig. 15 shows a drawing indicating the lens unit of the first element being a cylindrical concave lenticule lens.

Fig. 16 shows a drawing indicating the lens unit of the first element being a convex prism lenticule lens.

Fig. 17a, b show the drawings indicating the lens unit of the first element being an anisotropic lenticule lens.

Fig. 18 shows the way the angular distribution of the emission light brightness level is being measured by turning the lens surface to a mirror.

Fig. 19a, b show the drawings indicating the emission light distributions of the cylindrical convex lenticule lens in the front surface and back surface types, respectively.

Fig. 20a, b show the drawings indicating the emission light distributions of the triangle-columnar lenticule lens in the front surface and back surface type, respectively.

Fig. 21a, b show the drawings indicating the emission light distributions of the

cylindrical concave lenticule lens in the front surface and back surface type, respectively.

Fig. 22 a, b show the drawings indicating the emission light distributions of the convex prism lenticule lens in the front surface and back surface types, respectively.

Fig. 23a, b show the drawings indicating the emission light distributions of the anisotropic lenticule lenses A and B, respectively.

Fig. 24a, b show the drawings indicating the front surface type and the back surface type surface-light source elements using the cylindrical concave lenticular lens, respecively.

Fig. 25a, b show the drawings indicating the emission light distributions of the front surface and back surface type surface-light source elements having a cylindrical convex lenticule lens, respectively.

Fig. 26a, b show the drawings indicating the emission light distributions of the front surface and back surface type surface-light source elements using a triangle-columnar lenticule lens.

Fig. 27a, b show the drawings indicating the emission light distributions of the front surface and back surface type surface-light source elements having a cylindrical convex lenticule lens, respectively.

Fig. 28a, b show the drawings indicating the emission light distributions of the front surface and back surface type surface-light source elements having a convex

prism lenticule lens, respectively.

Fig. 29a, b show the drawings indicating the emission light distributions of the front surface and back surface type surface-light source elements having the anisotropic lenses A and B, respectively.

16. Lens unit

40. Prism unit

13. Reflection surface

14. Light source

15. Reflector

50. First element

51. Second element

30. Light-emission surface